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THE FRESH-WATER BIOLOGICAL STATIONS OF AMERICA.

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THE fundamental purpose of all biological stations, both marine and fresh-water, is essentially the same. They serve to bring the student and the investigator into closer connection with nature, with living things in their native environment. They facilitate observation and multiply opportunities for inspiring contact with, and study of, the living world. They encourage in this day of microtome morphology the existence and development of the old natural history or, in modern terms, œcology, in the scheme of biological education.

The predominance of the marine station is but natural, for American biology was cradled at Nahant and Penikese. Until recently, practically all the great centers of biological investigation and instruction have been located almost within sound of the sea. It was also to be expected that the seaside laboratory would attract the inland biologist who is searching for a place in which the summer can be passed with both pleasure and profit, and that the abundance and novelty of the marine fauna would overshadow if not entirely eliminate all attention to the fresh-water fauna of the vicinity, attractive though it might be.

This supremacy of interest in marine biology is not, however, confined to the seaside laboratory; it finds its way into textbooks and schoolrooms. Laboratory guides in which marine types very largely predominate are not unknown, and too many a teacher of biology in collegiate courses and in the secondary schools of our inland towns depends upon marine forms for laboratory study and demonstration, to the sad neglect of the fauna with which both he and his pupils come in daily contact. From a pedagogical point of view this element of remoteness in the objects of study is unfortunate, for it tends to abridge the sympathetic contact with nature and the development on the part of the pupil of a lively interest in the world of life about him, a feature of large cultural value in all biological education.

The writer has found a widespread feeling in biological circles that the fresh-water environment affords far less of value for investigation and instruction than the marine. Considered merely volumetrically, the marine fauna may well have the advantage, but all the general problems of biology can be approached with ease, and at times to even greater advantage at the fresh-water station; and, furthermore, in variety and richness the fauna of fresh water, in some localities at least, compares very favorably with that at the seaside. It may then be that one of the functions of the fresh-water station is to preserve and foster an interest in fresh-water life and to emphasize its availability and utility for purposes of instruction. In no sense of the word, however, are the marine and fresh-water stations to be regarded as rivals; each is the necessary complement of the other, and both alike have their place in the field of biology.

The movement which has resulted in the establishment of a number of fresh-water biological stations in the north central states in the past few years has had a variety of sources. Prominent among these have been, doubtless, the successful examples of the marine stations, and the desire on the part of inland workers to have near-at-hand resorts for summer work which should offer to their students analogous advantages without the expense attendant upon a trip to the seashore. The

existence in some of the states in question of natural history surveys under the patronage of the state has in a few instances been the means of furnishing the funds for the conduct of these enterprises. The fundamental reason, however, for the biological station movement is neither a mere local demand nor an opportune opening, but a deep-seated purpose on the part of the men who stand as sponsors for the stations, to extend biological exploration, to increase the facilities for, and raise the standard of, biological instruction in their respective states, and finally and principally to contribute in some substantial way to the solution of some of the fundamental problems of biology, as, for example, the problem of variation, or the œcology of a river system.

Aside from the three stations noticed at length in this article, whose past history and material equipment entitle them to recognition as permanent institutions, there have been other enterprises which have done the work of a biological station, though not formally organized as such. The fortunate situation of the University of Wisconsin upon the shores of Lake Mendota, rendering unnecessary the establishment of an independent outpost, has made it possible for Professor Birge to carry on for several years past a series of connected observations upon the Crustacea of the plankton. The results of this work—a credit to any biological station—have been published by the Wisconsin Academy of Sciences.¹ The work of exploration in this state will be continued elsewhere during the present summer under the auspices of the State Survey.

The Michigan Fish Commission for several years carried on a biological examination of many of the smaller lakes of the state. Professor Reighard, of the University of Michigan, was in charge of the work, and in 1893 made a more thorough and systematic survey of Lake St. Clair. In 1894 a biological examination of the northern end of Lake Michigan was made by a party in charge of Dr. H. B. Ward. The results of these explorations have appeared from time to time in the Bulletin of the Commission. The work upon the Great Lakes will be resumed this summer under the auspices of the United States

¹ See review in this journal, No. 376, pp. 282-284.

Fish Commission by a party in charge of Professor Reighard, located at Put-in-Bay, in Lake Erie.

The University of Minnesota maintained for several years at Gull Lake a laboratory for summer work in connection with the Natural History Survey of that state. The establishment of a station has also been agitated in the state of Iowa during the past year. The University of Rochester is raising funds for the equipment of a station at Hemlock Lake, thirty miles south of Rochester, in western New York. This station will probably be opened next year, and will occupy buildings furnished by the city of Rochester. Instruction will be the main purpose of its organization.

The description of the Ohio station, given herewith, was one of the last pieces of work which its late director, Prof. D. S. Kellicott, accomplished before his fatal illness. The account of the Indiana station was furnished by its director, Prof. Carl Eigenmann.

THE LAKE LABORATORY OF THE OHIO STATE UNIVERSITY.

This laboratory is at Sandusky, on the grounds of the city's pumping station, near a cove of the East Bay. It consists of the second story of the State Fish Hatchery; there is one large room with work table, and three small ones for the use of investigators. The supply of trawls, plankton nets, seines, insect nets, etc., is ample. Microscopes, reagents, and glassware are supplied as needed from the university. There is also a small sailboat. The most pressing needs, by way of equipment, are better aquaria and a larger and more seaworthy boat; these will be added in the future.

Sandusky is as favorable a place for the study of fresh-water fauna and flora as is likely to be found on the Great Lakes. Many species of fish spawn in the bays or about the adjacent islands; crustaceans, worms, sponges, and protozoans are abundant. If one wants a most favorable place to study water birds, none is better in this latitude than the extensive marshes and sand dunes in the vicinity of Sandusky.

The purpose of the station is simply to afford a convenient plant for students and instructors of the State University first, and any one else when there is room, to study the living forms of this favorable locality.

Work has been carried on at Sandusky for two summers. Some of the lines of work undertaken, in which progress has been made, are these: (*a*) fishes inhabiting the bays, their food and parasites; (*b*) nesting habits of the marsh-inhabiting birds; (*c*) the aquatic insects; (*d*) the Rotifera; (*e*) the fresh-water sponges; (*f*) the crayfishes. Some progress has been made in determining the amount, character, and distribution of the plankton.

The collections are mostly transferred to the university, and abstracts of the work reported to the Ohio Academy of Science, usually as reports of progress on the biological survey, which is being directed by a committee of the academy. The station will be open but a short time in 1898, as the survey is to be carried on in other parts of the state.

This station is in no sense a school; every man looks after his own interests, giving and receiving advice, as occasion may demand.

THE BIOLOGICAL STATION OF INDIANA UNIVERSITY.

A biological station for the Indiana University was suggested by Professor Eigenmann to the Board of Trustees in 1893, and he was enabled to open the station in 1895. The object in view being well defined and a number of localities being from a natural standpoint equally suitable, the location was determined by the finding of an old boathouse suited to the purpose on the shores of Turkey Lake. Windows were cut, boards laid to cover the larger cracks in the floor, and work begun.

As there was no fund available to defray the expenses of the station, a number of courses of instruction were offered to raise the necessary money, to permit a few "laboratory grubs" to attain their full development, and to start a few other students at work in the natural habitat of the beginner in zoölogy—the woods, the water, and the fields.

During that year a map was made of the lake bottom, a brief survey of the animal contents was undertaken; and material was collected for the main object of the station, the study of variation.

The trustees appropriated in the two years following \$200 and \$300, respectively, to provide permanent equipment to carry on the work and furnish accommodations for additional students.



INDIANA BIOLOGICAL STATION.

A building 18×55 feet, two stories high, was erected for the station by the owner of the ground.

The conditions for biological work, coupled with camp life on a fine lake, five miles from the nearest village, free from the university lecture-hour appointments, proved so attractive that during the second summer the number of students rose from 19 to 32, and in the third to 68.

The advantages for biological work at a biological station all recognize to be ideal; here some of the enthusiasm of the older natural history is aroused. To the special advantages mentioned should be added the acquisition on the part of the student of the ability to help himself, to adapt himself to new environments. Most of the failures by teachers of biology in the secondary

as well as higher schools have come from their inability to work with the means found at hand, and their inability to adapt themselves to a new environment.

The object of the station can best be expressed in the words of the first announcement.

RESEARCH. — The main object of the station will be the study of variation. For this purpose a small lake will present a limited, well-circumscribed locality, within which the differences of environmental influences will be reduced to a minimum. The study will consist in the determination of the extent of variation in the non-migratory vertebrates, the kind of variation, whether continuous or discontinuous, the quantitative variation, and the direction of variation. In this way it is hoped to survey a base line which can be utilized in studying the variation of the same species throughout their distribution. This study should be carried on for a series of years, or at least be repeated at definite intervals to determine the annual or periodic variation from the mean. A comparison of this variation in the same animals in other similarly limited and well-circumscribed areas, and the correlation of the variation of a number of species in these areas will demonstrate the influence of the changed environment, and will be a simple, inexpensive substitute for much expensive experimental work.

For this work the situation of Lake Wawasee, surrounded as it is by other lakes, some of them belonging to other river basins, will be admirably adapted.

In connection with this study of the developed forms the variation in the development itself will receive attention ; for instance, the variation in segmentation, the frequency of such variation, and the relation of such variation in the development to the variation in the adult, and the mechanical causes affecting variation.

INSTRUCTION. — Courses of instruction which ordinarily cannot be given in the university's laboratories during the college year will be offered, and credit given on the university's records. The courses are as follows :

1. *Elementary work.* The class will collect, preserve, and study a series of animals occurring in the neighborhood of the station. Emphasis will be laid on the nature of the fresh-water fauna, and the correlation and adaptation of organisms. The entire day will be given to collecting excursions, laboratory work, and lectures, with individual work on Saturdays. No special preparation is needed. (Teachers may collect material for their classes, but alcohol for this purpose will not be furnished.) 2. *Embryology* and life history of fishes and other local forms. 3. *Special investigations* in the variation of non-migratory vertebrates and survey of the physical and biological conditions of Lake Wawasee.

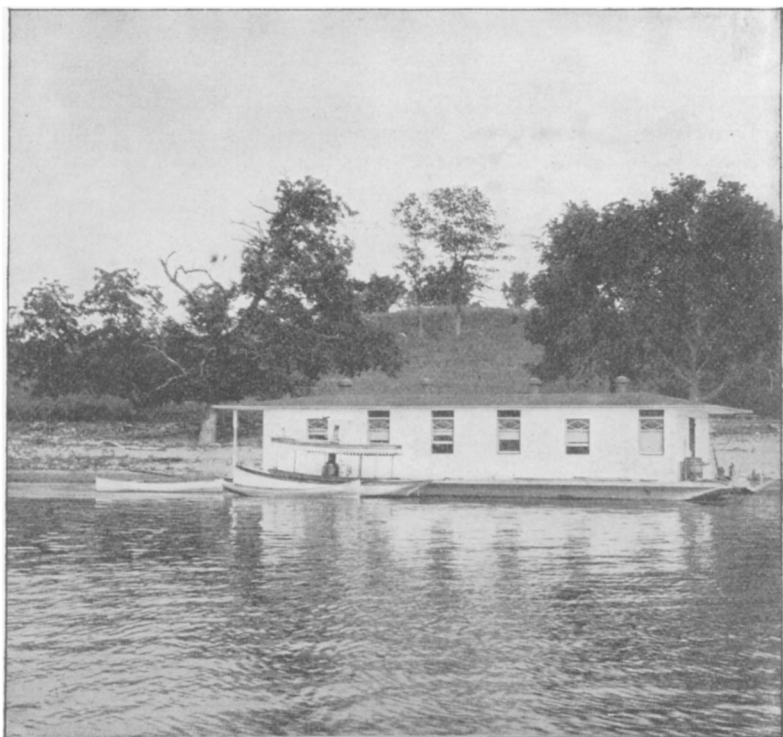
During the second and third years maps of a number of northern lakes have been prepared. A general survey of the Turkey Lake fauna has been published. A very large amount of material has been collected to illustrate the annual variation, the birth-mean, and the effect of selective destruction. Two papers on variation have been published, but most of the material is still to be examined.

As to the future, the Winona Assembly has offered to erect two buildings, each 20×57 feet and two stories high, on the shores of Eagle or Winona Lake, Indiana, eighteen miles from our present location. This lake had been decided upon for the location of the station in the first instance, but was given up because no suitable building was available. The trustees of the university have agreed to appropriate \$1000 for the permanent equipment of these buildings. They will be ready for occupancy in 1899. Aside from laboratories for bacteriology, physiology, embryology, zoölogy, and botany, there will be about a dozen small rooms for the instructors and for visiting naturalists who care to make use of the facilities offered. Courses of instruction will be offered in the subjects mentioned. The study of variation will be continued and other problems will be added, one of which will be the rearing of cave animals in the light.

ILLINOIS BIOLOGICAL STATION.

For a number of years the investigation of the aquatic life of the lakes and streams of Illinois has been prosecuted under the auspices of the State Laboratory of Natural History, in connection with the Natural History Survey now in progress in the state, under the direction of Prof. S. A. Forbes. From time to time parties equipped for biological exploration have been sent out, and have occupied temporary posts of observation on the Mississippi River or elsewhere. No permanent station was established, however, until April, 1894, when, with the joint support of the State Laboratory of Natural History and the University of Illinois, a station was opened upon the Illinois River at Havana. For the equipment of this work \$1800 was

appropriated. For the two years beginning July 1, 1895, this joint support was continued, \$2500 being appropriated by the legislature for equipment, and \$3000 per year for running expenses. In 1897 the appropriation for running expenses of the station was renewed, but the whole amount was given



ILLINOIS BIOLOGICAL STATION.

through the State Laboratory of Natural History, and the name of the station was changed from "The Biological Experiment Station of the University of Illinois" to "Illinois Biological Station."

From its beginning the station has enjoyed the deep interest and wise guidance of its experienced director, Prof. S. A. Forbes. Until July 1, 1895, the station was in the immediate charge of Prof. Frank Smith; since that date the conduct of its operations has been in the hands of the present superintendent.

The equipment of the station consists of a house boat or floating laboratory, 20 × 60 feet over all, well lighted and ventilated, containing a private laboratory and office, a main laboratory, a storeroom, and a kitchen. In the center of the larger laboratory stands a long sink for aquaria, supplied with water from an overhead tank. The tables in the laboratories will provide working accommodations for twenty persons. A steam launch, licensed to carry seventeen passengers, furnishes a convenient means of transit to and from the various collecting grounds, and a half-dozen rowboats add to the facilities for field operations. The station is supplied with nets and seines of various kinds for the collection of fishes and other aquatic vertebrates, with a collecting lantern and nets for field work in entomology, with a large number of breeding cages for the rearing of aquatic larvæ of insects, with dredges, sieves, dip nets, and Birge nets for bottom and shore examinations, and with tow nets, plankton nets, pumps, centrifuges, and counting machines for the qualitative and quantitative investigation of the plankton. The laboratory is also supplied with a number of aquaria, a liberal allowance of glassware and reagents, and in its more extended summer operations is further furnished from the biological laboratories of the university.

The library of the State Laboratory of Natural History is exceptionally complete in the literature of fresh-water fauna and flora, and is available for the use of the biological station. The leading monographs and many of the scattered papers dealing with the Protozoa, Rotifera, Oligochæta, Entomostraca, and aquatic insects are provided. Systematic and faunistic work upon these groups is further facilitated by the large number of collections in the possession of the state laboratory from the waters of the state and many other parts of the continent. Among the collections is a series of named European Entomostraca sent by eminent specialists (Sars, Schmeil, Lilljeborg, and Poppe); these are of great value in unraveling the synonymy of this group, and in establishing the validity of American species or their identity with European forms. They also afford a basis for the study of comparative variation in the two continents.

The field of operation of the station is, for the present at least, the Illinois River and its related waters. Geologists tell us that this stream and its bottom lands occupy the bed of an ancient river, a former outlet of Lake Michigan. The present flood plain is but slightly above the level of the river, and overflows are, therefore, of more than usual extent and frequency. The fall of the stream is very slight, about thirty feet in two hundred and twenty-five miles, and at times of flood the area covered is over seven hundred square miles. Over fifty-six square miles in the field of the station's operations are submerged at high water, and of these seventeen represent the river, lakes, bayous, and permanent marshes of low-water stages. The extreme fluctuation in the river level recorded at Havana is eighteen feet, and a rise to sixteen feet above low water is not unusual in the spring or early summer. Owing to dams, the river at low water is practically a series of slack-water pools. The river thus presents a considerable change in conditions during the year. Although at high water it is practically a unit in environment, as the water recedes a number of distinct and characteristic aquatic areas emerge, and are quickly differentiated by their peculiar fauna and flora. At low water there thus lies within easy reach of the station a wide range of situations, including the river and its tributary streams, Spoon and Quiver Rivers, a shallow ephemeral lake quite free from vegetation, a large impounding lake and bayou without tributaries, several spring-fed lakes with different amounts of vegetation, and a number of marshes of varying degrees of permanence. This extremely varied environment, and the considerable and sometimes sudden fluctuations in the water level, add greatly to the complexity of the biological problems with which our station has to deal.

The fertility of the drainage basin of the river, the large amount of sewage emptying into the stream, and the rich alluvial soil of the bottom lands favor the growth of aquatic vegetation. At low water a rank growth of *Ceratophyllum* fairly chokes many of the lakes, and at times even encroaches upon the river. *Nelumbium* and *Nymphæa*, *Lemna*, *Wolffia*, and *Azolla* abound, and water-blooms of *Euglena*, *Carteria*,

Anabæna, and Clathrocystis are of frequent occurrence. The plankton is remarkable alike for the large number of individuals and of species it contains, while in volume per cubic meter it, at times, exceeds almost all published records. The fauna, as well as the flora, is conspicuous for its abundance and variety. Although no efforts have been made to accumulate complete faunal lists, over one hundred species of Protozoa have been recorded, as well as a like number of Rotifera. Spoon River has long been noted for the abundance, variety, and size of its Unionidæ, thirty species of which are known to occur in the vicinity of Havana; there are in addition forty-five other species of aquatic Mollusca, largely univalves. Through the efforts of Professor Smith over thirty species of Oligochæta have been found, including a number of new and interesting forms. Aquatic insects abound, over three hundred and fifty species being known to occur in the vicinity. An interesting feature of the richness of the fauna is the occurrence of certain zoölogical rarities whose range, as hitherto known in this continent at least, has been limited; as, for example, Urnatella and Lophopus among the Bryozoa, and Trochosphæra among the Rotifera.

The essential objects and general methods of the Illinois station are best expressed by its director, Professor Forbes, in his last biennial report.

It is the general, comprehensive object of our biological station to study the forms of life, both animal and vegetable, in all of their stages, of a great river system, as represented in carefully selected typical localities. This study must include their distinguishing characters, their classification and variations, their local and general distribution and abundance, their behavior, characteristics, and life histories, their mutual relationships and interactions as living associates, and the interactions likewise between them and the inanimate forms of matter and of energy in the midst of which they live. We are, in short, to do what is possible to us to unravel and to elucidate in general and in detail the system of aquatic life in a considerable district of interior North America.

So vast a subject must of course be intelligently divided and studied part by part, in some systematic order, to avoid a dissipation of effort and to insure the speedy attainment of some definite and tangible results. Its most obvious divisions are the systematic, the biographical, and the æcological;

and this is the order, broadly speaking, in which the general investigation must be carried on. Both systematic and biographical biology have a high independent value in our scheme, but both are with us chiefly means to the remoter end of a study of the interactions of associate aquatic organisms, and of their relations to nature at large. It is thus the œcological idea which is to lead in the organization and development of our work. A systematic survey of the biological assemblage is a necessary preliminary step, and the tracing of life histories and the recognition and description of immature stages is a scarcely less essential prerequisite; for without the knowledge which these studies are to give us, it would be obviously impossible to make any comprehensive study of variations, distribution, and œcological relationships.

The œcology of the Illinois River is greatly complicated, and the difficulty of its study intensified, by certain highly and irregularly variable elements of the environment. Apart from those secular and more or less inconstant features of climate and weather which must be taken into account wherever such studies are prosecuted, we often have here the evidently very large and highly intricate reactions produced by periodic variations in the river level, and the consequent enormous extensions and corresponding diminutions of the mass of the waters and of the area covered by them. Fortunately for the possibilities of success in so difficult a field, progress in it does not require that the entire system of life should be studied as a unit at first. Special problems may be selected, of a kind to be brought easily within the available time and the capacities of the individual investigator, which, being worked out one by one, may be later brought together as contributions to a solution of the larger problems involved.

In actual practice it has been found that our work may best be opened up by comprehensive studies of the classification, such as will give us a critical knowledge of all the forms occurring in our field, and access to the published literature of each; and by parallel or slightly subsequent studies of their habits, life histories, and local distribution and abundance.

The principal methods of the biological station are those of field and laboratory observation and record, collection, preservation, qualitative and quantitative determination, description, illustration, generalization, experiment, induction, and report.

By close and persevering observation in the field, we learn much of the actions, habits, and haunts of animals, of the special conditions under which they live, and of many similar matters which cannot possibly be learned in any other way; and not a little of this knowledge is necessary to an intelligent treatment of both general and special problems in biology.

The acute, persevering, sympathetic observer of living nature — the “old-fashioned naturalist,” in short — is best to be understood as a “synthetic

type," all of whose best qualities should be not only preserved but intensified among his variously differentiated progeny. It is the biological station, wisely and liberally managed, which is to restore to us what was best in the naturalist of the old school united to what is best in the laboratory student of the new.

As our work progresses and special problems are taken up for separate and continuous investigation, the experimental method will necessarily come prominently into use. The object of biological experimentation is the interpretation of nature, and, like all intelligent experimental work, it must be suggested and guided by observation and hypothesis. With us it is the ecological field in which experiment is especially called for. Given certain phenomena of local distribution, of relative abundance, of association, of habit, of variation, and the like, whose causes it is desirable to ascertain, it is incumbent upon us, by a critical and exhaustive study of the environment to find the materials for rational hypotheses as to such causes, and to test such hypotheses by experimental procedure. It is thus always the field observation, or the laboratory observation made under conditions which involve the least practicable departure from natural conditions actually existing, which must precede and suggest the experiment. The method and the general object of this work resemble thus more closely, on the whole, those of the agricultural experiment station—which is, indeed, a biological station under another name and devoted to a special end—than those of the laboratory of experimental physiology; and it is because ours is to be in the end and in its final objects a station for the solution, by experimental methods, of both special and general problems in the field of ecology that it was christened by its official board of control the Biological *Experiment* Station of the University.

As the work of the station is still in its earlier stages, the papers thus far published give the results of the preliminary explorations, and, consequently, are of a systematic, faunistic, or biographical character in the main. A report upon the aquatic Hymenoptera and a considerable portion of the Diptera and Lepidoptera, by Mr. C. A. Hart, has already been published, and additional papers upon the Odonata and Ephemeroidea are in preparation. It is the purpose of these papers to elucidate the life histories of the insects of these groups by giving a detailed account of the identified eggs, larvæ, and pupæ, together with a discussion of their seasonal and local distribution, their habitat, food, etc. As a result of the breeding work carried on at the station, immature stages, hitherto undescribed, of two hundred and twenty-five species have been obtained.

The investigation of the Oligochæta has been carried on for several years; thirty species are known to occur. Two new genera and at least seven new species have been found. Three papers have appeared upon the subject, and a final report is in preparation by Professor Smith. The results of the examination of the Turbellaria of the station have been published by Dr. W. McWoodworth, seven species being found, of which two are new. Some new species of Rotifera and Protozoa have been described by Mr. A. Hempel, and a report upon the local and seasonal distribution of these groups has been completed. Three papers upon the Entomostraca, prepared as zoölogical theses by students in the university, have been based in part upon station collections. A report upon the Ostracoda of North America, by R. W. Sharpe, a revision of the North American species of the genus *Diaptomus*, by F. W. Schacht, and a paper upon the North American species of Cyclopidae, by E. B. Forbes, have appeared, and a fourth paper upon the remaining genera of the Centropagidae is ready for the press.

The plankton work of the station has resulted in the accumulation of a large number of collections and a mass of data upon the local and seasonal distribution of pelagic organisms. Considerable attention has been given to the sources of error in the plankton method, and efforts have been made to secure a reliable and convenient basis for the quantitative and statistical study of the aquatic world.

Although the station was established primarily for purposes of investigation, its relation to biological education has not been neglected. As soon as permanent quarters were occupied, the facilities of the station were thrown open to students and teachers, twenty of whom availed themselves of the privilege in 1896. No formal instruction was given, each person following his own inclination as to the line of work undertaken, with such incidental guidance and assistance as the station staff could afford. A summer school with definite courses, especially for teachers, was planned for 1897, but, owing to the temporary loss of funds for the maintenance of the station, the project was abandoned. For the summer of 1898 an offer is made of elementary and advanced courses in both botany and zoölogy.

These courses will be supplementary to regular university work, and will, to some extent, be especially adapted to the needs of teachers of biology in the secondary schools. Tables at the station will also be reserved for the use of visiting investigators and students of special subjects.

For the successful accomplishment of the fresh-water work certain desiderata are evident: more precise and reliable methods for the quantitative and statistical study, not only of the plankton, but also of shore and bottom forms; more biographical work, studies of life histories in the broadest sense of the term, including precise observations upon the environment and its relation to the life cycle; more models of experimental work that shall make clear the feasibility of the application of the methods of the physiological laboratory to the study of the factors of environment; more biological stations, so that the conclusions arrived at in one locality may be extended and corrected in a score of others; and, finally, some biological Fröbel, who shall demonstrate the disciplinary and cultural value of oecology as a field of biological instruction and establish a standard for others to imitate.

The future of the fresh-water biological stations is bright with the hope of accomplishment, but their problems lie not wholly along the beaten paths of the past. In their work we may look for the happy combination of the sympathetic observation of the old-time naturalist, the technical skill and searching logic of the morphologist, and the patient zeal and ingenuity of the experimental physiologist, a combination, let us hope, that shall unlock not a few of the secrets of the world of life.